National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

North Coast and Cascades Network Climate Monitoring Report

Lewis and Clark National Historical Park; Water Year 2010

Natural Resource Data Series NPS/NCCN/NRDS—2012/325

ON THE COVER
Wetland located northwest of McKenzie Head, Camp Disappointment State Park
Photograph by: Mount Rainier National Park

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the North Coast and Cascades Network Inventory and Monitoring website (http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/).

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Contents

Figures

Page

Tables

Page

Executive Summary

Climate and weather events define the ecological characteristics found in National Parks and are key to understanding and interpreting changes in natural resources. Everyday park operations including fire management, natural resource activities, maintenance of park infrastructure, and visitor use are influenced by weather. Monitoring weather and maintaining climate records provides essential information to support park operations and monitor park resources.

This report summarizes climate data collected at weather stations within and adjacent to Lewis and Clark National Historical Park from the 2010 water year. It is part of a set of climate summary reports from seven national and historic parks in the North Coast and Cascades Network. Published in the National Park Service's Natural Resource Data Series, annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. We envision National Park staff, especially, planners, scientists, interpreters, partners; and interested public as the primary audience for these reports.

Temperature and precipitation data are presented from four weather stations located along the Pacific Coast from Northern Oregon to Southern Washington. Data were recorded using automated and manual instruments operated by the National Weather Service and Federal Aviation Administration. For two stations with long term records; the Astoria Regional Airport Automated Surface Observing Systems (ASOS)/Cooperative Observer Station (COOP) Station and Long Beach COOP Station, monthly average temperatures and monthly total precipitation are reported and compared to the 30-year normal. For all stations, monthly air temperature and precipitation data are displayed. Daily precipitation and average daily temperature are presented for three stations.

Weather data collected in water year 2010 indicated that average annual temperatures were near normal with slightly above normal annual precipitation. Overall, conditions during the winter months were warmer than normal, but shifted to cooler and wetter conditions during the spring months.

Acknowledgments

The National Park Service relies on the National Weather Service Cooperative Observer Program to help support and maintain a long-term climate monitoring program as part of the North Coast and Cascades Network (NCCN) climate monitoring program. These agencies include:

- Federal Aviation Administration and Department of Defense – Automated Surface Observing Systems

- National Weather Service – National Weather Service Cooperative Observer Program

Data management is critical for the availability and analysis of climatic data. We rely on the NCCN Data Managers, specifically John Boetsch, Bret Christoe, the Western Regional Climate Center, and the National Climate Data Center for climate data management.

The authors appreciate the careful review by Chris Clatterbuck, Lewis and Clark National Historical Park and Barbara Samora, Mount Rainier National Park.

Acronyms

ASOS	Automated Surface Observing Systems
COOP	Cooperative Observer Station
FAA	Federal Aviation Administration
I&M	Inventory and Monitoring
LEWI	Lewis and Clark National Historical Park
NCCN	North Coast and Cascades Network
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NWS	National Weather Service
PNW	Pacific Northwest
WRCC	Western Regional Climate Center

Glossary

ASOS: The Automated Surface Observing Systems program is a joint effort of the National Weather Service, the Federal Aviation Administration and the Department of Defense. The program operates a network of automated weather stations at airports nationwide, for the purpose of supporting weather forecast activities and aviation operations.

Climate: Complete and entire ensemble of statistical descriptors of temporal and spatial properties comprising the behavior of the atmosphere. These descriptors include means, variances, frequency distributions, autocorrelations, spatial correlations and other patterns of association, temporal lags, and element-to-element relationships. The descriptors have a physical basis in flows and reservoirs of energy and mass. Climate and weather phenomena shade gradually into each other and are ultimately inseparable (Davey et al. 2006).

Climate Normals: A long-term average value of a meteorological parameter (i.e. temperature) for a certain area. For example, "temperatures are normal for this time of year" means that temperatures are at or near the average climatological value for a given time period. Normals are usually taken from data averaged over a 30-year period (e.g., 1971-2000 average), and are concerned with the distribution of data within limits of common occurrence.

Fall: The season of the year which is the transition period from summer to winter occurring as the sun approaches the winter solstice. Fall includes the months of September, October and November.

NWS-COOP: An extensive network of manually operated weather stations overseen by the National Weather Service. Many Cooperative Observer Program weather sites were established in the late 1800's and as such, provide the best long term data for understanding local climates. At each station, an observer records daily maximum and minimum temperature, as well as total rain and snowfall.

Period of Record: The total span of time that climate data have been collected at a specific location. The longer the period of record, the more likely the climate data will not be biased by singular weather events or cyclic climate anomalies such as those associated with the Pacific Decadal Oscillation.

Spring: The season of the year comprising the transition period from winter to summer occurring when the sun is approaching the summer solstice. Spring includes the months of March, April and May.

Summer: The warmest season of the year during which the sun is most nearly overhead. Summer includes the months of June, July, and August.

Water Year: The Water Year (or Hydrologic Year) is most often defined as the period from October 1st to September 30 of the following year. It is called by the calendar year in which it ends. Thus, Water Year 2010 is the 12-month period beginning October 1, 2009 and ending September 30, 2010. The period is chosen so as to encompass a full cycle of precipitation accumulation.

Weather: Instantaneous state of the atmosphere at any given time, mainly with respect to its effects on biological activities. As distinguished from climate, weather consists of the short-term (minutes to days) variations in the atmosphere. Popularly, weather is thought of in terms of temperature, precipitation, humidity, wind, sky condition, visibility, and cloud conditions (Davey et al. 2006).

Winter: Typically the coldest season of the year during which the sun is farthest from overhead. Winter includes the months of December, January and February.

Introduction

Climate is a dominant factor driving the physical and ecologic processes affecting the North Coast and Cascades Network (NCCN) (Davey et al. 2006). Changes in precipitation and temperature can influence how an ecosystem and its organisms function. For example, the quantity and timing of rainfall and snow can affect the productivity and health of forests (Nakawatase and Peterson 2006), the amount of water flowing in streams and rivers (Hamlet et al. 2007) or wetland inundation. Likewise, temperature can influence many aspects of ecosystems, such as the quantity and timing of plant growth in forests and prairies (Cayan et al. 2001), distribution and migratory behavior of bird communities (Marra et al. 2005), or the thermal stress experienced by intertidal organisms along areas of rocky coastline (Tomanek and Helmuth 2002). Through direct and indirect methods, climate affects the behavior and reproduction of terrestrial and aquatic animal species (Crozier et al. 2008). Disturbance events such as forest fires, windstorms, and floods are strongly related to climate (Littell and Gwozdz 2011). These events have a major impact on park landscapes and their associated ecosystems.

Given the importance of climate, it has been identified as a primary vital sign by all 32 Inventory and Monitoring (I&M) networks within the National Park Service (Gray 2008). The NCCN monitors climate in order to understand variations in other park resources being monitored, compare current and historic data to understand long-term trends, and provide data for modeling impacts to park facilities and resources in the future (Lofgren et al. 2010). Climate data, derived from the NCCN climate network will play an important role in understanding and interpreting the physical and ecological Vital Signs monitored within NCCN parks.

The NCCN climate monitoring program capitalizes on weather stations operated by partnering agencies. The NCCN climate monitoring program compiles data from over 60 weather stations in and adjacent to the parks, 15 of which are operated by the National Park Service. Although a wide variety of climate parameters are measured as part of the NCCN climate program, this report focuses on two key parameters: precipitation and air temperature.

The report summarizes climate data collected from four weather stations located in and adjacent to Lewis and Clark National Historical Park during the 2010 water year, and is part of a set of climate summary reports from seven national and historic parks in the NCCN (see Figure 1). Annual climate summary reports are intended to provide basic data sets and data summaries in a timely manner, with minimal interpretation and analyses. National Park staff, especially park managers, scientists, and interpreters, partners, and interested public are the primary audience.

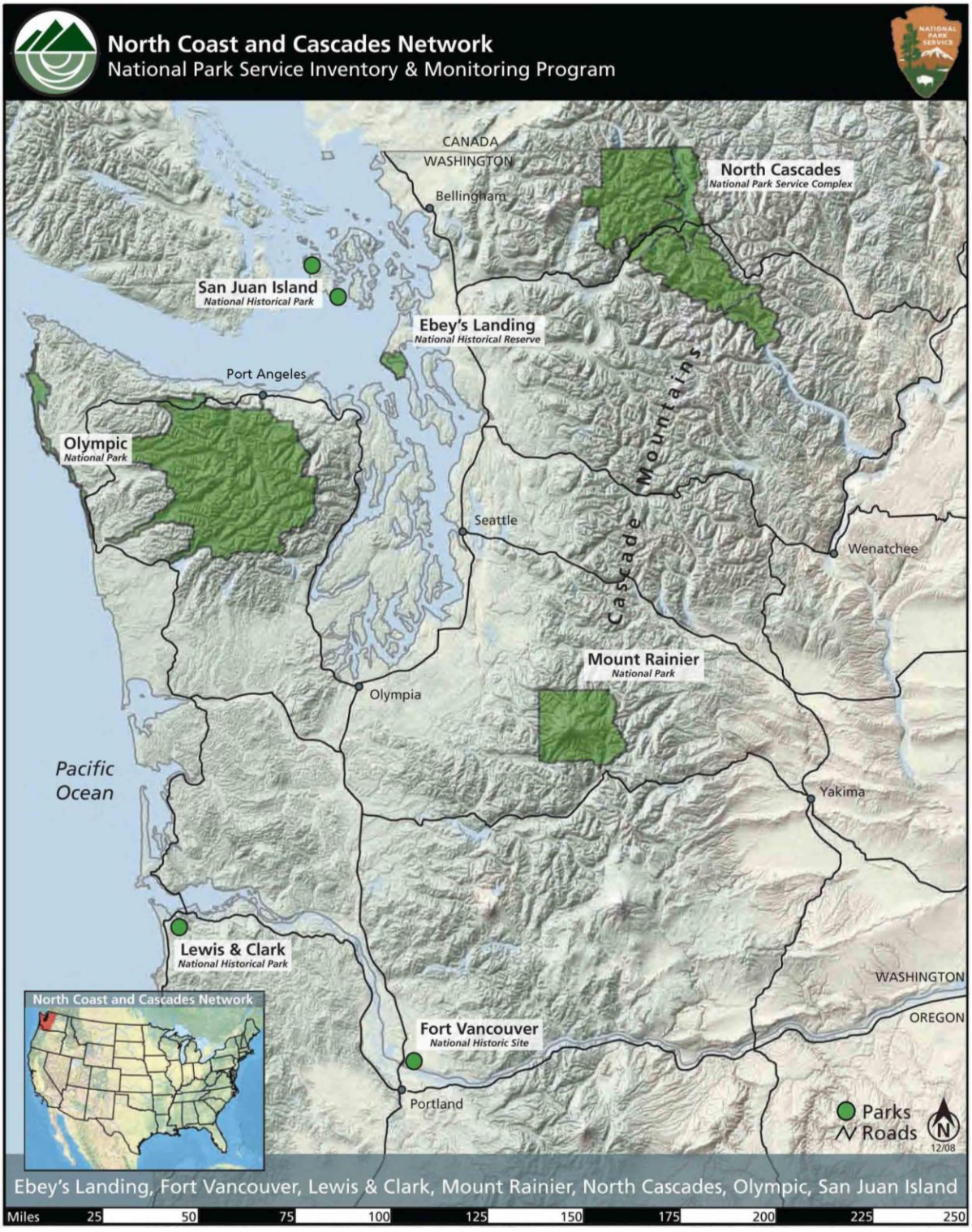

Figure 1. North Coast and Cascades Network National Parks (NCCN).

Methods

Station Locations

This report incorporates data collected from weather stations operated by the National Weather Service (COOP) and the Federal Aviation Administration (ASOS) (Table 1).

Table 1. Weather stations referenced in this report.

Station Name	Station Type	Location	Elevation (ft)	Forest Zone	Period of Record
Fort Clatsop	COOP	Fort Clatsop, OR	42	Coastal	1998 to Present
Astoria WSO Airport	ASOS, COOP[a]	Astoria, OR	9	Coastal	1953 to Present
Seaside	COOP	Seaside, OR	10	Coastal	1967 to Present
Long Beach Exp. Stn.	COOP	Long Beach, WA	30	Coastal	1930 to Present

[a]An ASOS was installed in March, 1993. Manual COOP observations continued until approximately 1998. Automated data from the ASOS station is used by the COOP network to continue the long term weather record.

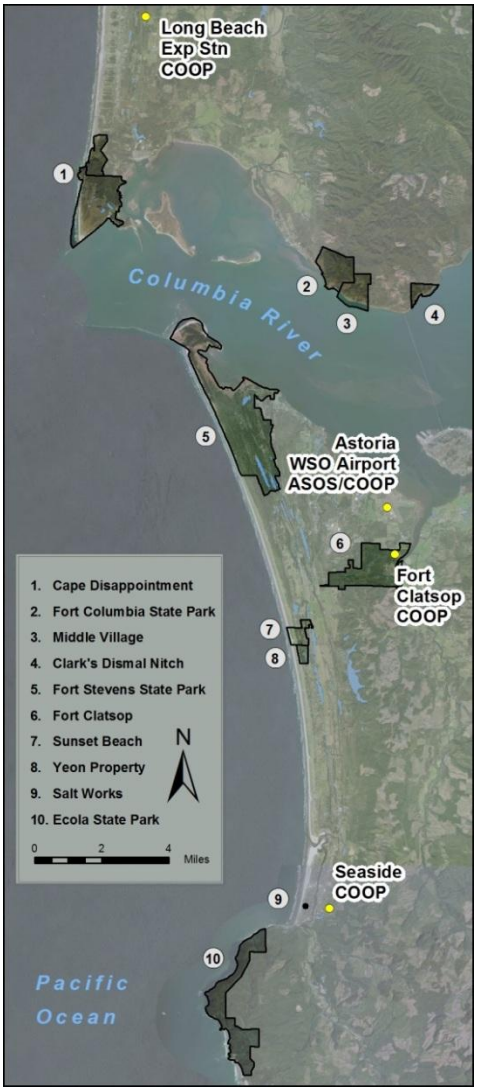

Figure 2. Location of weather stations referenced in this report.

Weather Station Measurements

Weather stations within or adjacent to LEWI are managed by several different agencies, each with a specific purpose. For this reason, instrumentation, method and period of collection vary between sites. Table 2 describes the parameters measured at each station, highlights the data which are presented in this report, and indicates which data are available by request from the NCCN.

Table 2. Parameters measured at weather stations included in this report. **X** indicates the parameter is measured and data are presented in this report; **X** indicates parameter is measured and data are available on request.

Station Name	Managing Agency - Station Type	Air Temp	Rh	Precipitation	Snow fall	Visibility/Sky Condition	Wind Speed & Direction
Fort Clatsop	NWS-COOP[1]	**X**		**X**	X		
Astoria WSO Airport[2]	NWS-COOP[1] FAA-ASOS[2]	**X**	X	**X**	X	X	X
Seaside	NWS-COOP[1]	**X**		**X**	X		
Long Beach Exp Stn.	NWS-COOP[1]	**X**		**X**	X		

[1] National Weather Service Cooperative Stations (NWS COOP) stations rely on a standard array of manually operated weather instruments. Parameters are measured and recorded daily.

[2] An ASOS (Automated Surface Observing System) was added to the Astoria WSO Airport COOP in March, 1993. Wind speed and direction, visibility and sky condition are available after 1993. Manual observations continued to approximately 1998. Automated data from the ASOS station is used by the COOP network to continue the long term weather record. ASOS utilize a standard array of automated weather instruments in support of weather forecasting and aviation operations. Parameters are measured every 60 seconds, and output as hourly averages. These stations are managed and operated by the Federal Aviation Administration, National Weather Service and United States Department of Defense.

Data Quality

Precipitation data from the Seaside COOP weather station during the month of June appeared suspect when compared to other stations referenced in this report. Weather stations located in Long Beach and Fort Clatsop National Memorial, which normally correlate well with Seaside, reported significantly less rainfall during the month of June (4.9 and 5.0 inches, compared to 12.1 inches at Seaside) (Table 4). When daily precipitation data was compared between sites, Seaside COOP recorded 8 inches of rain on June 9th, while Fort Clatsop COOP and Long Beach Experimental Station recorded 0.72” and 0.68”, respectively. These data are provided by the National Weather Service and are derived from volunteer observations and it is likely this value was recorded or transcribed incorrectly. A correction of the daily precipitation value to 0.80” results in total monthly precipitation value at Seaside of 4.9”, well within range of the adjacent weather stations. More than 5 days of temperature data are missing from the Seaside COOP in the month of January and all temperature and precipitation data are missing from the Seaside COOP during the month of September. Given the number of missing data and errors associated

with the Seaside COOP, daily temperature and precipitation graphs are not included in this report.

Monthly total precipitation for the Long Beach Experimental Station COOP in the month of May is suspect due to poor correlation of monthly and daily data with adjacent weather stations. Precipitation appears to be underrepresented by approximately 1 to 2 inches.

Data Management

The NWS COOP station data used in this report are acquired directly from the managing agencies. Quality assurance and control is provided by these agencies and is described in the NCCN Climate Monitoring Protocol (Lofgren et al. 2010).

Monthly values are generated and presented for stations where five or fewer daily values are missing. In the case of missing precipitation values, daily quantities may be substituted from another nearby weather station for the purposes of reporting monthly and annual totals. This will only occur when nearby data are available and a known correlation exists between these sites. In these cases where estimates are generated from nearby stations, data are footnoted and a description of the quantity and source of data replacement is given.

Data Reporting

Data in this report are based on the hydrologic or water year and organized by month and seasons. Ecosystems in the Pacific Northwest are dominated by two distinct hydrological periods, a wet season generally beginning in late October and ending in June, and a drought season which extends from July to September. While a calendar year divides the wet winter season, the use of a water year (October 1 to September 30) closely reflects the timing and seasonality of many physical and ecological processes that are driven by climate, such as soil saturation, forest evapotranspiration, emergence and flowering of plants, and the migratory timing of bird species.

Seasons in this report are distinguished based on National Weather Service standards for the Northern Hemisphere which defines December, January, and February as winter; March, April, and May as spring; June, July, and August as summer; and September, October, and November as fall.

This report provides monthly averages of daily average temperatures and monthly total precipitation for four stations listed in Table 2. The data are presented in Fahrenheit and inches to easily facilitate use and interpretation by the public and park staff. Two stations with long term records: the Astoria WSO Airport ASOS/COOP located 2 miles north of Fort Clatsop, and the Long Beach Experimental Station COOP located 4 miles north of Camp Disappointment State Park are compared to the 30-year climate normal. Daily precipitation and temperature data are presented for the Astoria WSO Airport ASOS/COOP, Fort Clatsop COOP, and Long Beach Experimental Station COOP. Maximum daily wind speed is presented for the Astoria WSO Airport ASOS/COOP only since wind speed data are not collected from the other stations.

Results

Temperature

Mean annual temperatures were near normal at weather stations within or adjacent to LEWI (Table 3). Following a colder than normal December (departures of -2.6° and -3.2°F at Astoria, OR and Long Beach, WA respectively), warmer than normal temperatures dominated for the remainder of winter (Figures 3 and 4). January had the highest observed deviation with departures of +5.9° and +5.3°F at Astoria and Long Beach, respectively. A shift to cooler than normal weather occurred in March and lasted through August (Figures 3 and 4).

During a prolonged cold period in early December, notably low daily temperatures were recorded. Long Beach recorded an absolute low of 14.0°F on December 8. On the same day Fort Clatsop National Memorial, recorded a low of 16°F (Table 5).

Table 3. Average monthly air temperatures (°F) from weather stations within or adjacent to LEWI in Water Year 2010.

Season	Month & Year	Astoria ASOS/COOP	Long Beach COOP	Fort Clatsop COOP	Seaside COOP
Fall	October 2009	53.4	51.0	52.0	52.3
	November 2009	48.5	46.8	47.0	49.3
Winter	December 2009	40.2	38.9	38.3	39.7
	January 2010	48.3	46.9	46.9	49.2[a]
	February 2010	47.7	46.2	46.8	48.8
Spring	March 2010	48.2	47.0	46.9	48.3
	April 2010	48.7	47.7	47.9	48.5
	May 2010	51.0	51.0	50.7	49.6
Summer	June 2010	56.3	54.8	55.6	53.9
	July 2010	59.5	57.2	57.7	57.1
	August 2010	60.2	58.3	59.8	58.0
Fall	September 2010	59.8	57.9	58.6	----[b]
Water Year		**51.8**	**50.3**	**50.7**	**----**
Period of Record 1971-2000		**51.6**	**50.0**	**----**	**52.6**

[a] More than 5 days of temperature data are missing from the Seaside COOP in the month of January.

[b] Temperature data from the Seaside COOP are missing for the entire month of September.

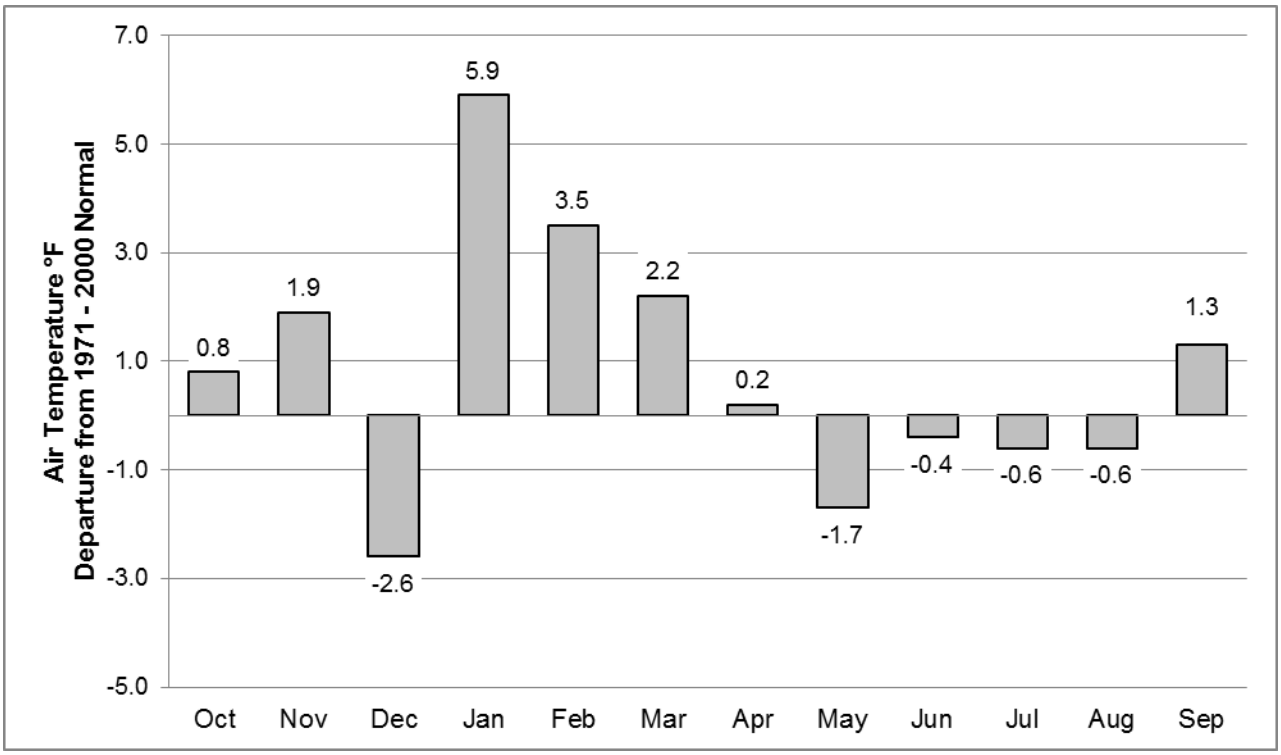

Figure 3. Comparison of average monthly temperature (°F) for Astoria, OR (ASOS, COOP) in Water Year 2010 against monthly averages for the climatological normal 1971-2000.

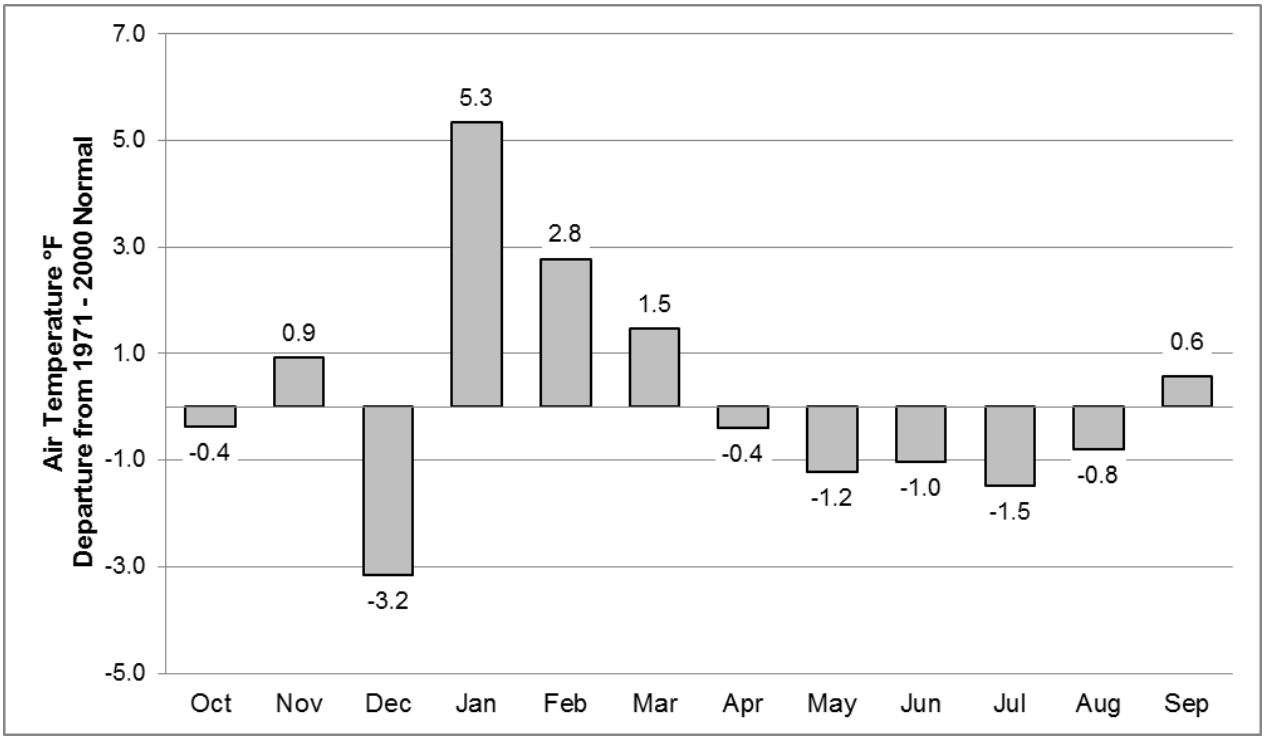

Figure 4. Comparison of average monthly temperature (°F) for Long Beach, WA (COOP) in Water Year 2010 against monthly averages for the climatological normal 1971-2000.

Table 4. Maximum and minimum daily air temperatures (°F) for each month from weather stations within or adjacent to LEWI in Water Year 2010.

		Fort Clatsop		Astoria		Long Beach	
Season	**Month & Year**	**Max Daily Air Temp °F**	**Min Daily Air Temp °F**	**Max Daily Air Temp °F**	**Min Daily Air Temp °F**	**Max Daily Air Temp °F**	**Min Daily Air Temp °F**
Fall	October 2009	65.0	34.0	66.0	37.0	63.0	34.0
	November 2009	62.0	34.0	64.0	35.0	63.0	34.0
Winter	December 2009	54.0	16.0	57.0	15.0	54.0	14.0
	January 2010	59.0	32.0	63.0	33.0	58.0	30.0
	February 2010	60.0	34.0	63.0	30.0	61.0	29.0
Spring	March 2010	66.0	32.0	67.0	33.0	66.0	30.0
	April 2010	66.0	35.0	64.0	37.0	60.0	34.0
	May 2010	67.0	33.0	65.0	36.0	64.0	37.0
Summer	June 2010	75.0	38.0	71.0	43.0	66.0	40.0
	July 2010	92.0	40.0	93.0	47.0	92.0	41.0
	August 2010	91.0	42.0	90.0	46.0	92.0	45.0
Fall	September 2010	80.0	44.0	83.0	45.0	78	42
Water Year Maximum and Minimum		**92.0**	**16.0**	**93.0**	**15.0**	**92.0**	**14.0**

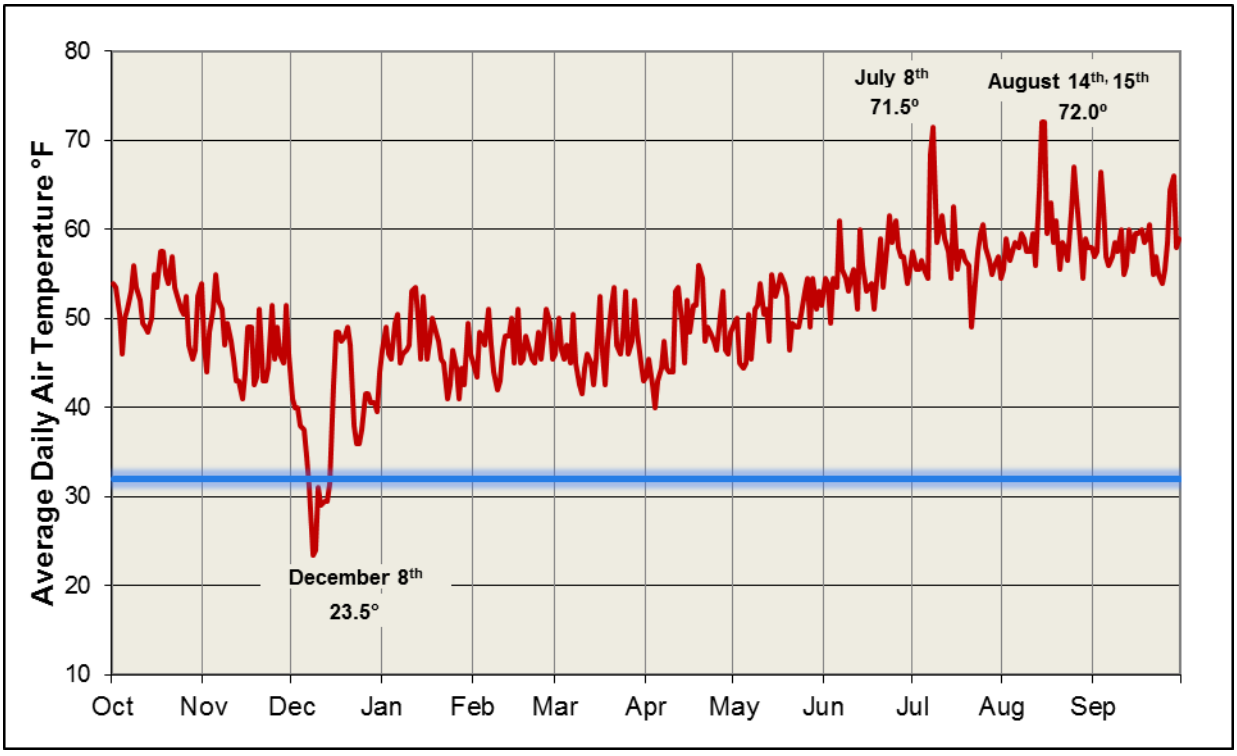

Figure 5. Daily average air temperature (°F) at Fort Clatsop, OR, Water Year 2010. Blue line indicates 32ºF, the freezing point of water.

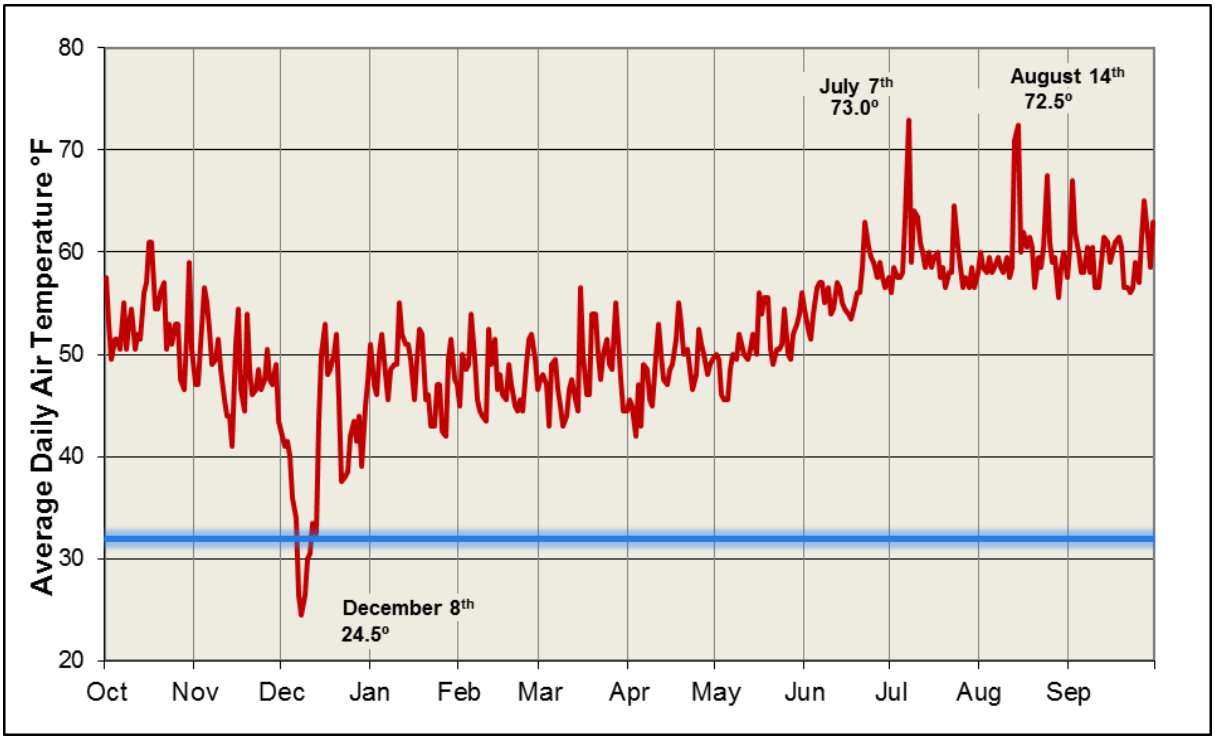

Figure 6. Daily average air temperature (°F) at Astoria, OR, Water Year 2010. Blue line indicates 32ºF, the freezing point of water. The difference between the warmest observed daily average in July by one day between Fort Clastop and Astoria is possibly due to the timing of data collection.

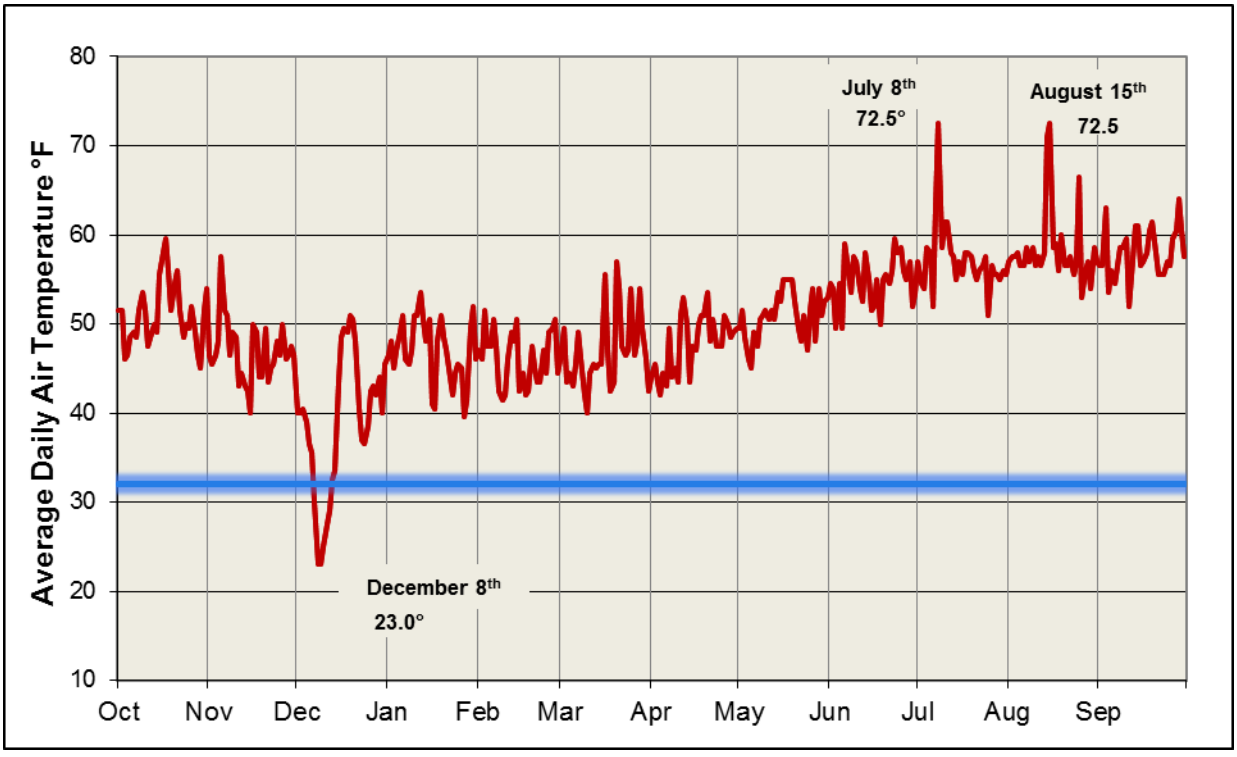

Figure 7. Daily average air temperature (°F) at Long Beach, WA, Water Year 2010. Blue line indicates 32ºF, the freezing point of water.

Precipitation

Annual precipitation in Water Year 2010 was above normal at weather stations within or adjacent to LEWI. Astoria, OR received 78.3 inches, 117 percent of normal. Long Beach, WA received 89.1 inches, 110 percent of normal (Table 5).

The late fall months were wetter than normal followed by an unusually dry December with both stations receiving less that 50% of normal. January, February, and March averaged near normal at both Astoria and Long Beach (Figures 8 and 9). Wet conditions returned in the spring and early summer, with Astoria averaging 148 percent of normal and Long Beach averaging 137 percent of normal for the period of April through June (Figures 8 and 9).

Late summer was relatively dry, especially the month of July, with stations receiving less than 50% of normal. September was much wetter than normal, receiving 2.7 and 4.1 inches of rain (175% and 171% of normal) at Astoria and Long Beach, respectively. The wettest day of the year occurred on November 17, 2009 with Fort Clatsop receiving 3.56 inches and Astoria Regional Airport receiving 2.71 inches (Figures 11 and 12). The difference in daily precipitation values between Fort Clatsop and Astoria is likely due to the timing of data collection. Daily rainfall totals are measured at midnight at the Astoria Regional Airport and at 10:00 am at the Fort Clatsop COOP.

Table 5. Total monthly precipitation (inches) from weather stations within or adjacent to LEWI in Water Year 2010.

Season	Month & Year	Astoria ASOS/ COOP	Long Beach COOP	Fort Clatsop COOP	Seaside COOP
Fall	October 2009	7.9	8.2	8.8	7.4
	November 2009	16.7	17.6	18.2	16.6
Winter	December 2009	5.7	6.2	5.3	6.3
	January 2010	11.2	13.2	12.6	10.8
	February 2010	7.4	8.9	7.7	9.5
Spring	March 2010	7.2	9.5	7.4	9.1
	April 2010	7.7	7.9	8.5	9.4
	May 2010	4.5	3.6[a]	5.1	5.9
Summer	June 2010	3.9	4.9	5.0	12.1[b]
	July 2010	0.6	0.9	0.8	0.7
	August 2010	1.1	1.5	0.7	1.2
Fall	September 2010	4.6	5.6	5.7	----[c]
Water Year		**78.3**	**88.1**	**85.8**	**----**
Period of Record 1971-2000		**67.1**	**81.2**	**----**	**75.8**

[a] Monthly total for Long Beach in the month of May is suspect due to poor correlation (both monthly and daily) with adjacent weather stations.

[b] Monthly total is likely incorrect due to an observer recording error. A correction to the 8" of rain recorded on June 9th to 0.80" gives a monthly total of 4.9".

[c] Precipitation data for Seaside COOP are missing for the entire month of September.

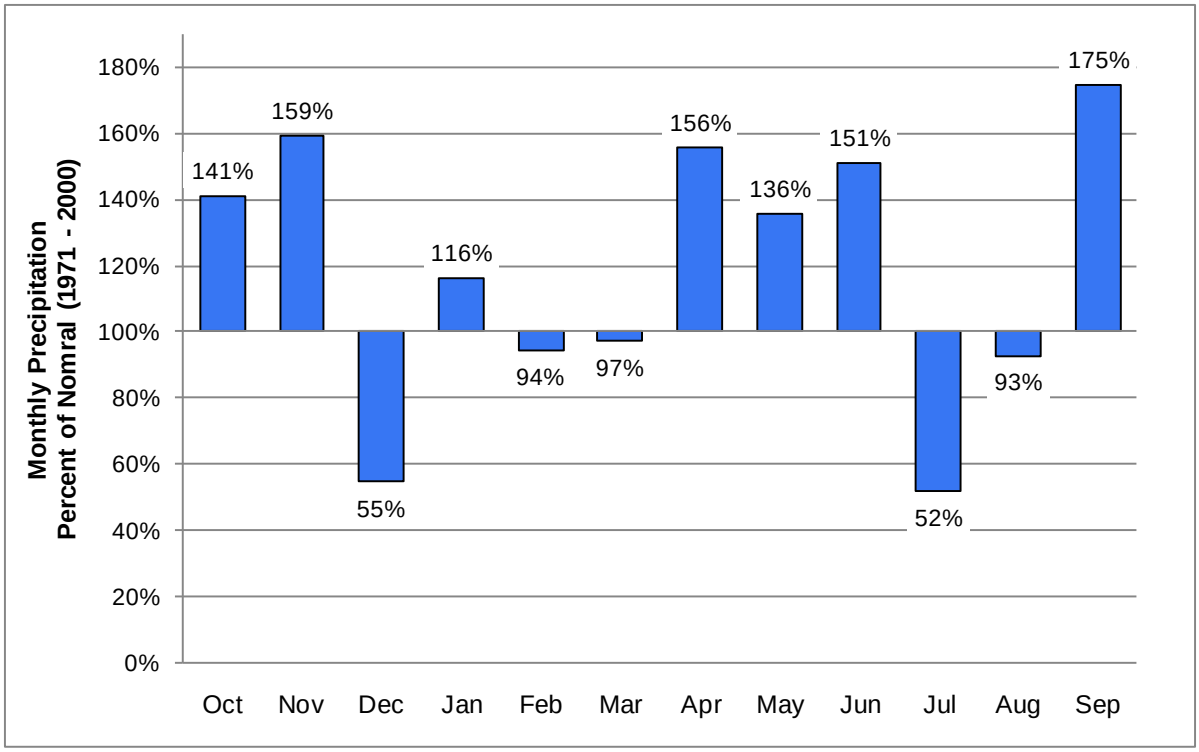

Figure 8. Comparison of total monthly precipitation (inches) at Astoria, OR COOP in Water Year 2010 against the monthly averages for the climatological normal period1971-2000.

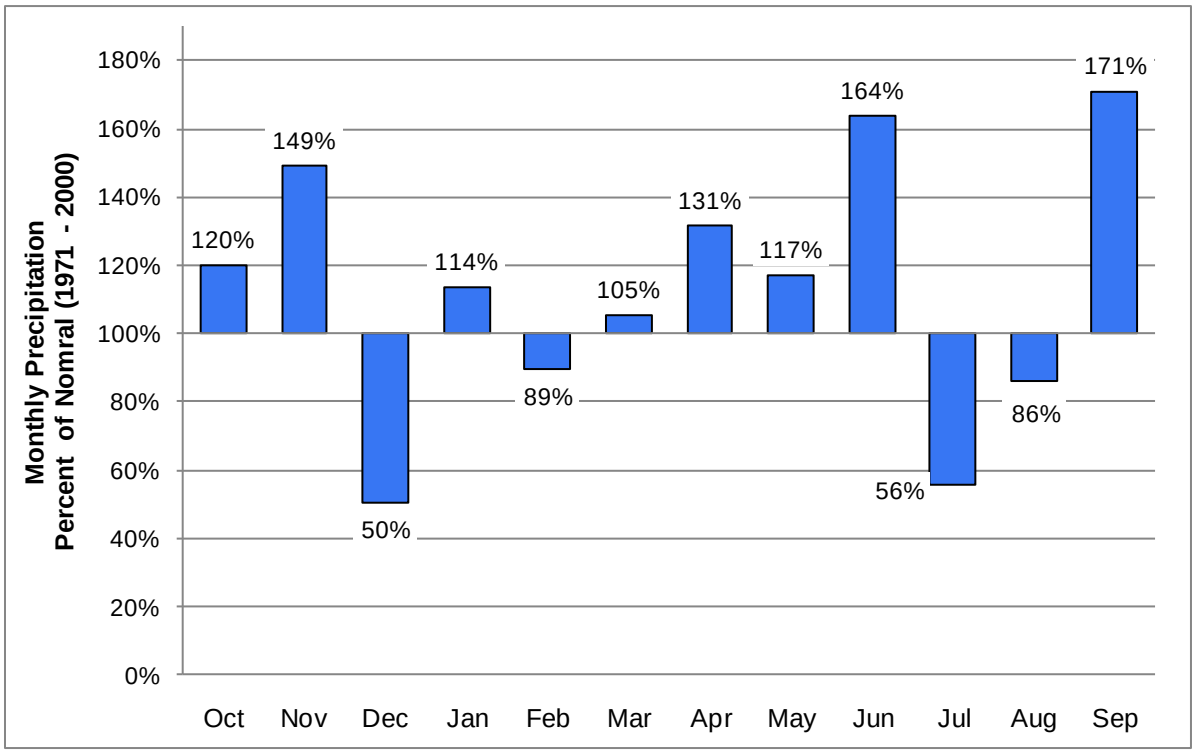

Figure 9. Comparison of total monthly precipitation (inches) at the Long Beach, WA COOP Station in Water Year 2010 against the monthly averages for the climatological normal 1971-2000.

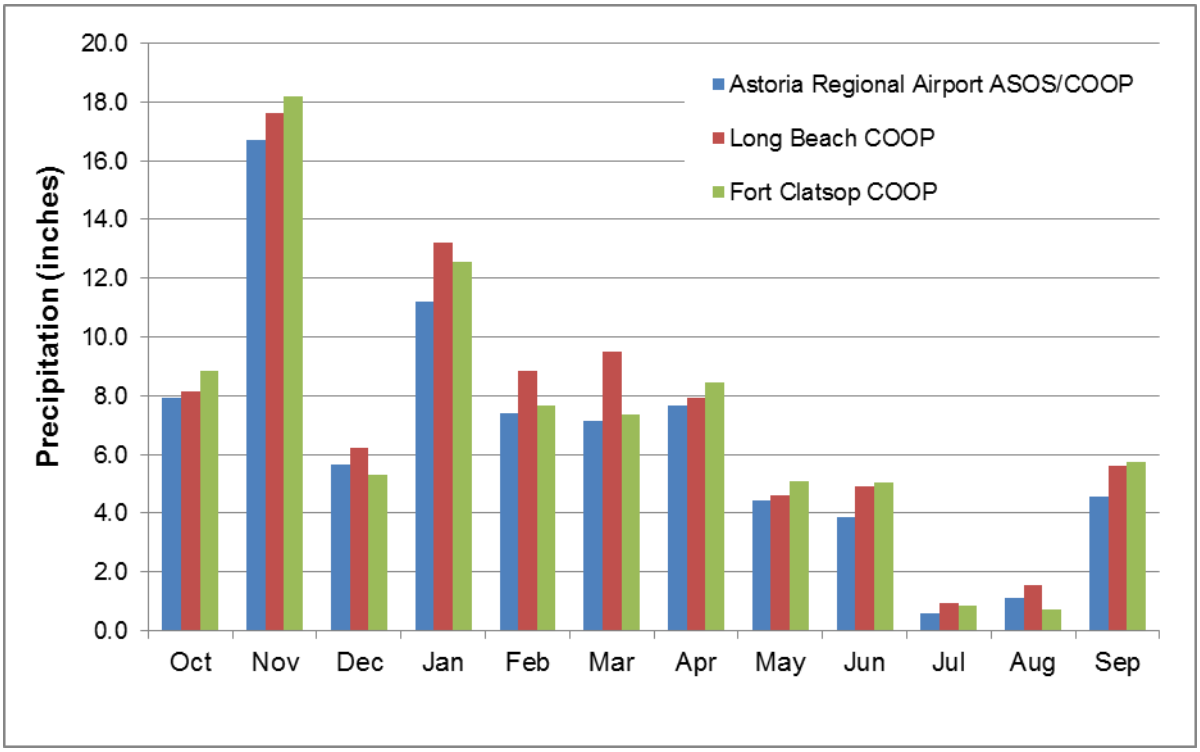

Figure 10. Comparison of monthly precipitation values for four stations within or adjacent to LEWI in Water Year 2010.

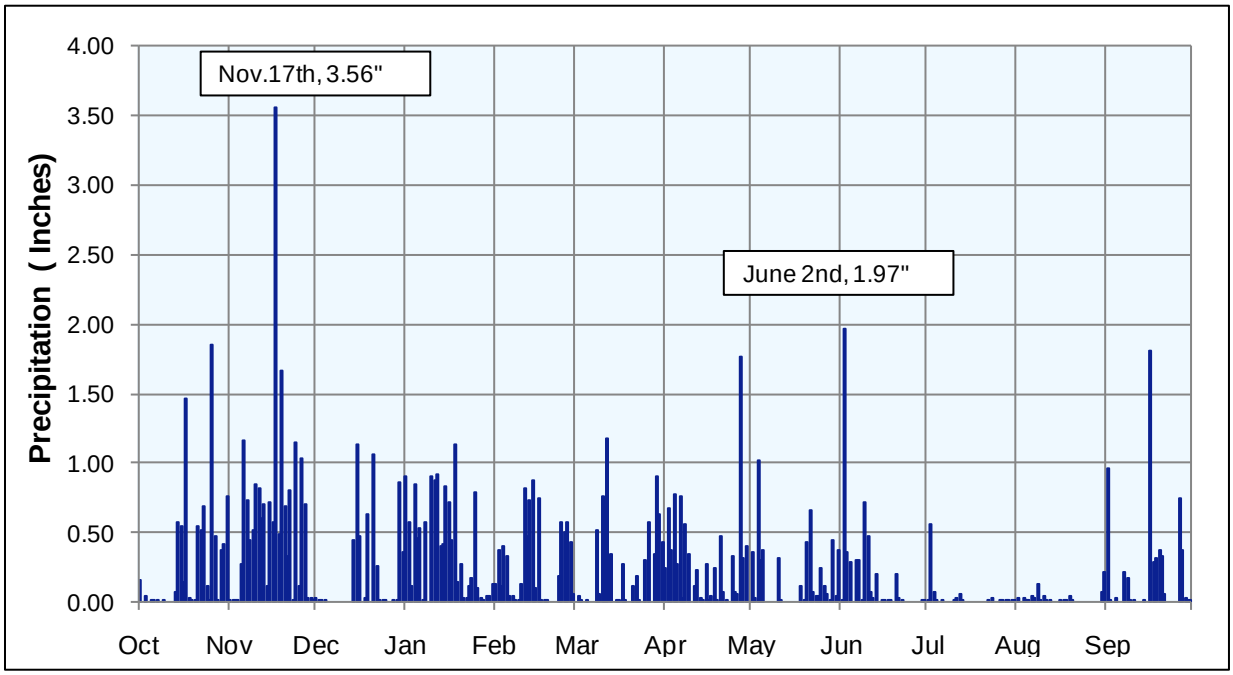

Figure 11. Daily precipitation (inches) at Fort Clatsop, OR, Water Year 2010. Daily rainfall totals are collected at 10am daily.

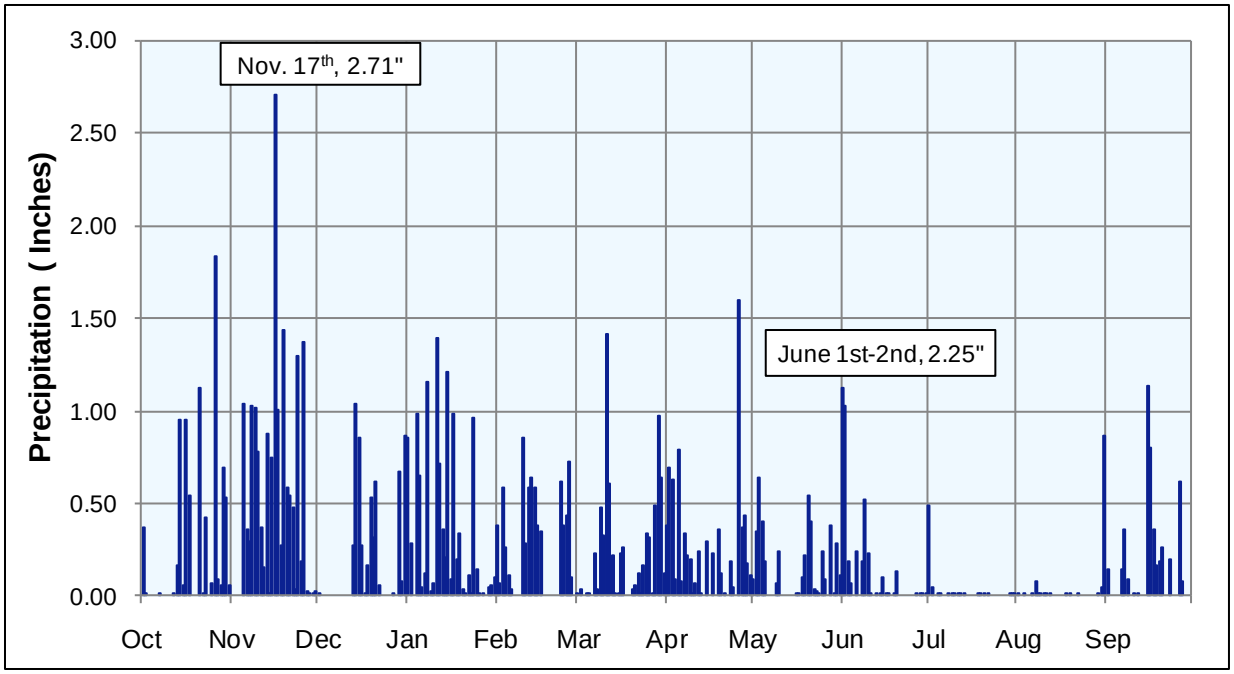

Figure 12. Daily precipitation (inches) at Astoria, OR, Water Year 2010. Daily rainfall totals are collected at midnight.

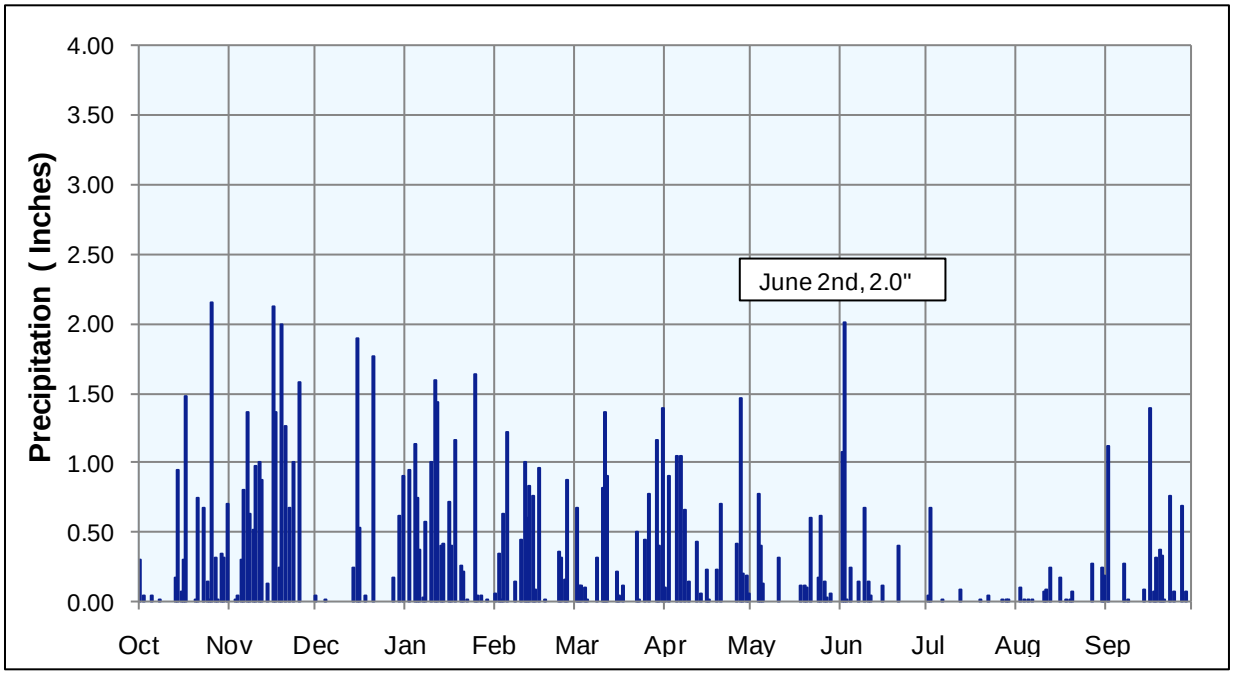

Figure 13. Daily precipitation (inches) at Long Beach, WA, Water Year 2010.

Wind

Maximum daily wind recorded at the Astoria Regional Airport in Water Year 2010 ranged from a low of 5.8 mph to a high of 40.3 mph recorded on January 18th (Figure 14).

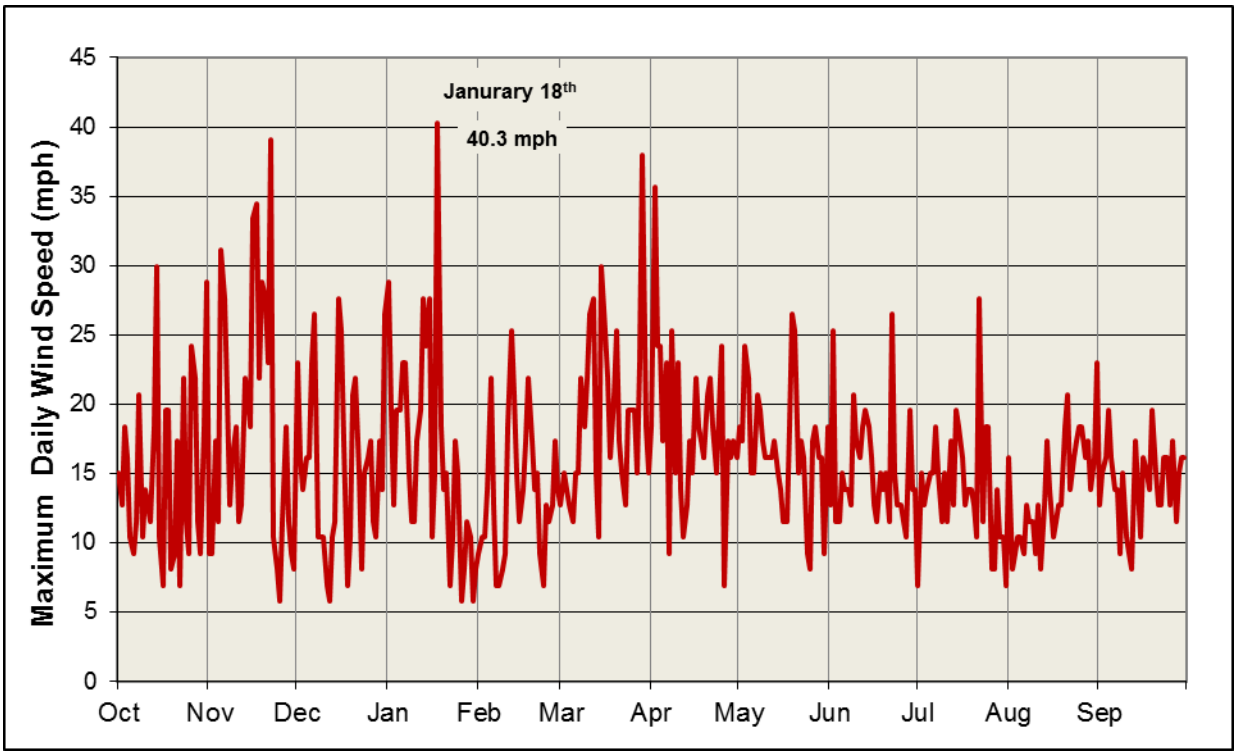

Figure 14. Maximum daily wind speed (mph) at Astoria, OR, Water Year 2010.

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